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November 30, 1978

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. NUCLEAR REGULATORY COMMISSION
Washington, D. C. 20555

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Attention: Mr. A. Schwencer, Chief
Operating Reactor Branch #1

Gentlemen:

POINT BEACH UNIT 1, CYCLE 7
STARTUP PHYSICS TESTING - ROD WORTH DATA

The startup physics testing of Point Beach Unit 1, at the beginning of Cycle 7, included rod worth measurements using a rod bank exchange technique sometimes referred to as the "rod swap" method. Ongoing discussions concerning the validity of this technique have taken place between Wisconsin Electric, Westinghouse, and the NRC Staff. Mr. Schwencer's letter of October 12, 1978, agreed that rod swap could be used for Unit 1, Cycle 7 startup. Wisconsin Electric committed to supply a written report of the measurement results within 45 days after completion of the test. This letter transmits that report in accordance with the requirements of your October 12, 1978 letter.

As can be seen in Attachment A, the worth of the banks was greater than 0.9 of the design worth. Therefore, the acceptance criterion was met. The preliminary evaluation of the test results with respect to the review criteria indicated that two review criteria were exceeded.

1. The reference bank worth appeared to be greater than 10% more than the predicted design worth. As discussed in Section 3.1 of the attachment, a complete evaluation of the test data indicates the reference bank worth to be within 10% of the predicted design worth.

2. Control Bank B worth appeared to be less than 85% of the design worth. The reevaluation of the reference bank data led to the conclusion that this bank also met the review criteria.

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The initial notification made on October 16, 1978, to Mr. Kohler, Office of Inspection and Enforcement, Region III that the above two review criteria had been exceeded was incorrect. This error occurred because evaluation of the test data had not been completed by the first working day following completion of the test at which time, as we understand it, a report was required to be made to the NRC. As discussed in Attachment A, the confusion in interpretation of the data has been resolved satisfactorily.

The attached report contains only the results of the rod swap test in accordance with item ') of the October 12, 1978 letter and fulfills our commitment to provide a report of the test results.

This has been the fourth time that the rod swap technique has been successfully utilized at Point Beach and the NRC has received a significant amount of data on its use. We therefore anticipate generic approval of the rod swap technique by the NRC Staff in the near future and tentatively plan to employ this method for the Unit 2, Cycle 6 startup testing in the spring of 1979. Assuming that generic approval is given, we do not plan on further reporting of startup rod worth measurement results for routine cycle startup testing.

Very truly yours,

T. R. Wilson

T. R. Wilson
Projects Administrator

ATTACHMENT "A"

1.0 INTRODUCTION AND SUMMARY

The purpose of this report is to document the results of the control rod worth verification tests performed during the beginning of Cycle 7 low power test program at the Point Beach Nuclear Plant Unit 1.

These tests utilized the rod exchange technique in which the integral reactivity worth of a control or shutdown RCC bank is obtained relative to a reference bank whose worth is measured directly.

This report is divided into three main sections: (1) a description of the test program including test conditions, sequence of events and test data; (2) a presentation of the test results including data analyses, corrections and comparison with design predictions and; (3) an evaluation of the test results.

2.0 TEST DESCRIPTION

The rod worth verification, utilizing rod exchange ("rod swap") was divided into two parts. In Part 1, the reactivity worth of the reference bank was obtained from reactivity computer measurements and boron end-point data during RCS boron dilution. In Part 2, the critical height of the reference bank was measured after interchange with each remaining bank.

Following Part 2, and at constant RCS boron concentration, a new critical configuration was established with Control Bank D fully inserted and C at 65 steps. The combined worth of Control Banks C and D was then measured with the reactivity computer during RCS boration to the all rods out condition.

Figure 1 is a plot of measured RCS boron concentration as a function of time and shows the sequence of events during the rod worth measurements.

2.1 Reference Bank (Control Bank A) Worth Measurement

In the rod exchange technique, the reference bank is defined as that bank which has the highest worth, of all banks, control or shutdown, when inserted into the core alone. For Cycle 7 the reference bank is Control Bank A (CA). Figure 2 shows the location of control and shutdown banks in the Point Beach cores.

Using an analog reactivity computer, reactivity measurements were made during the insertion of Control Bank A from the fully withdrawn to the fully inserted position. For these measurements, the reactivity computer used, as input, a signal proportional to the sum of the top and bottom detector currents of NIS power range CH42 (quadrant A-13). The average current during the measurement was approximately 1.5×10^{-7} amps, which had been determined previously to be at least a factor of 100 times the detector background current and less than the nuclear heating flux level.

Critical boron concentration measurements (boron endpoints) were made before and after the insertion of the reference bank.

Test results are presented in Section 3.

2.2 RCC Bank Interchange

The sequence of events during the rod interchange portion of the test is shown graphically in Figure 3.

Starting with an initial configuration with the reference bank fully inserted (0 steps) and all other banks fully withdrawn (228 steps) a new critical configuration at constant RCS boron concentration was established with Control Bank C fully inserted and Control Bank A at 114.5 steps. Control Bank C was then withdrawn and Control Bank A inserted to establish the initial conditions for the next exchange. This sequence was repeated until a critical position was established for the reference bank with each of the other banks individually inserted. Criticality determinations before and after each exchange were made with the reactivity computer.

A summary of the rod interchange data is presented in Table 1.

Analysis of the interchange data is presented in Section 3.

2.3 Worth Measurements of Control Banks C and D

Following the rod exchange measurements and a movable detector flux map with the reference bank inserted, the reactor was manually tripped. Criticality was restored, at the same boron concentration as prior to the trip, with Control Bank D at zero and Control Bank C at 65. The worth of Control Bank C from 65 to 228 steps and the worth of Control Bank D from 0 to 228 steps were subsequently measured with the reactivity computer during withdrawal (RCS boration) to all rods out condition. Critical boron concentration data were obtained prior to boration, with Control Bank D at 0 and with all rods out.

Test results presented in Section 3.

3.0 DATA ANALYSIS AND TEST RESULTS

3.1 Reference Bank Worth

In the test program, four separate pieces of data were obtained from which the worth of the reference bank was derived:

3.1.1 Reactivity computer measurements during Control Bank A insertion.

3.1.2 Boron endpoint data prior to and following Control Bank A insertion.

3.1.3 Reactivity computer measurements of Control Banks C and D following interchange with Control Bank A.

3.1.4 Boron endpoint data prior to and following Control Banks C and D withdrawal.

Within the accuracy of the measurement data, the values obtained from 3.1.2, 3.1.3 and 3.1.4 are consistent both internally and with design predictions. The value derived from the data of 3.1.1 is, however, inconsistent with 3.1.2, 3.1.3 and 3.1.4 and design predictions and is considered to be in error.

The error in the 3.1.1 measurement data is believed to be the result of a faster than normal RCS boron dilution rate (97 compared with a nominal 55 ppm/hour) during CA insertion. The consequent time between rod steps (about 30 seconds) is considered to be insufficient for asymptotic conditions in the core, and/or reactivity computer, to be achieved prior to the next required rod motion, in particular, where spatial redistribution effects are significant as in the Control Bank A measurements. This can introduce a bias in the test results consistent with the observed data.

The best estimate of the integral worth of the reference bank is 1696 pcm which is the combined worth of Control Bank C from 65 to 228 steps and Control Bank D from 0 to 228 steps measured with the reactivity computer during withdraw after iso-reactivity exchange with Control Bank A measurement 3.1.3. The RCS boron addition rate for these measurements was less than 70 ppm/hour.

The use of the 3.1.3 data for the integral worth of Control Bank A introduced a complication in deriving the inferred worths of the remaining control and shutdown banks which requires a plot of the measured integral reactivity of the reference bank as a function of inserted position. To complete the analysis, such a curve was generated by normalizing the predicted integral shape of Control Bank A to the measured value at the fully inserted position as shown in Figure 4. The use of the predicted axial shape is justified by the D worth shape, shown in Figure 5 and the measured axial flux shape in the movable detector flux maps Figures 6, 7 and 8 (ARO and Bank D in, HZP, and ARO, HFP) which verify nuclear design predictions.

For completeness, the reactivity measurement data of 3.1.1 are shown in Figure 9, labeled as questionable.

3.2 Inferred Integral Bank Worths

The integral reactivity worth of Bank X is inferred from the measurement data and design predictions through the equation:

$$W_x^I = W_R^M - (\Delta\rho_1)_x - \alpha_x (\Delta\rho_2)_x$$

Where

W_x^I = the inferred worth of Bank X, pcm.

W_R^M = the measured integral worth of the reference bank, Bank R, pcm.

$(\Delta\rho_1)_x$ = the measured integral reactivity worth of the reference bank from the fully inserted position to the average position before and after exchange with Bank X, pcm.

$(\Delta\rho_2)_x$ = the measured integral reactivity worth of the reference bank to the fully withdrawn position from the critical position with Bank X fully inserted, pcm.

α_x = a correction factor equal to the predicted ratio of the reference bank integral worth from h_x^P to the fully withdrawn position with and without Bank X present. h_x^P is the predicted reference bank position after exchange with Bank X.

3.2.1 Computation of $(\Delta\rho_1)_x$

The computation of the correction term for the reference bank not being fully inserted prior to the exchange is presented in Table 2. The integral worth to the fully inserted position of the reference bank was obtained from the worth measurements of the reference bank during dilution, shown in Figure 9. Because this data was obtained during the end of the dilution measurement when the reactivity addition was slow and the magnitude of the correction small, the data can be used for this application. In addition, the amount of reactivity below 20 steps is quite small.

3.2.2 Computation of $(\Delta\rho_2)_x$

Values of $(\Delta\rho_2)_x$ were obtained from Figure 4 and are tabulated in Table 2.

3.2.3 Computation of Inferred Bank Worths

Final values for the integral worth of control and shutdown banks inferred from the measurement data are tabulated in Table 3. Values for α_x were obtained from the design predictions and are listed in Table 2.

4.0 EVALUATION OF TEST RESULTS

A comparison of the measured/inferred individual bank worths with design predictions is presented in Table 3.

In evaluating the test results, three review and one acceptance criteria were used as follows:

4.1 Review Criteria

4.1.1 The measured worth of the reference bank agrees with design predictions within ±10%.

4.1.2 The inferred individual worth of each remaining bank agrees with design predictions within ±15%.

4.1.3 The sum of the measured and inferred worths of all control and shutdown banks is less than 1.1 times the predicted sum.

4.2 Acceptance Criteria

4.1.1 The sum of the measured/inferred worths of all control and shutdown banks is greater than 0.9 times the predicted sum.

As shown in Table 3, all review and acceptance criteria were met, demonstrating the adequacy of nuclear design rod worth predictions for Cycle 7.

TABLE 1

CRITICAL CONFIGURATION DATA

Point Beach Nuclear Plant
Unit 1 Cycle 7
October 14, 1978

Time (Hrs.)	RCS Tavg (°F)	RCS Boron Conc. (ppm)	Reference Bank Position (Steps)		RCC Bank Positions				
			$(h_x^M)_o$	(h_x^M)	No. 2 (CC)	No. 3 (SB)	No. 4 (SA)	No. 5 (CD)	No. 6 (CB)
1440	---	1265	0		228	228	228	228	228
1450	526.3			114.5	0	228	228	228	228
1458	526.9	1266	0[a]		228	228	228	228	228
1508	531.0			115.0	228	0	228	228	228
1523	529.0	1267	17		228	228	228	228	228
1532	529.1			126	228	228	0	228	228
1542	529.0		18		228	228	228	228	228
1552	529.0			94.5	228	228	228	0	228
1600	529.0		17		228	228	228	228	228
1608	529.0			85.5	228	228	228	228	0
1618	528.2	1266	16.5		228	228	228	228	228

a) Reactor supercritical by 3 pcm.

TABLE 2

SUMMARY OF MEASUREMENTS

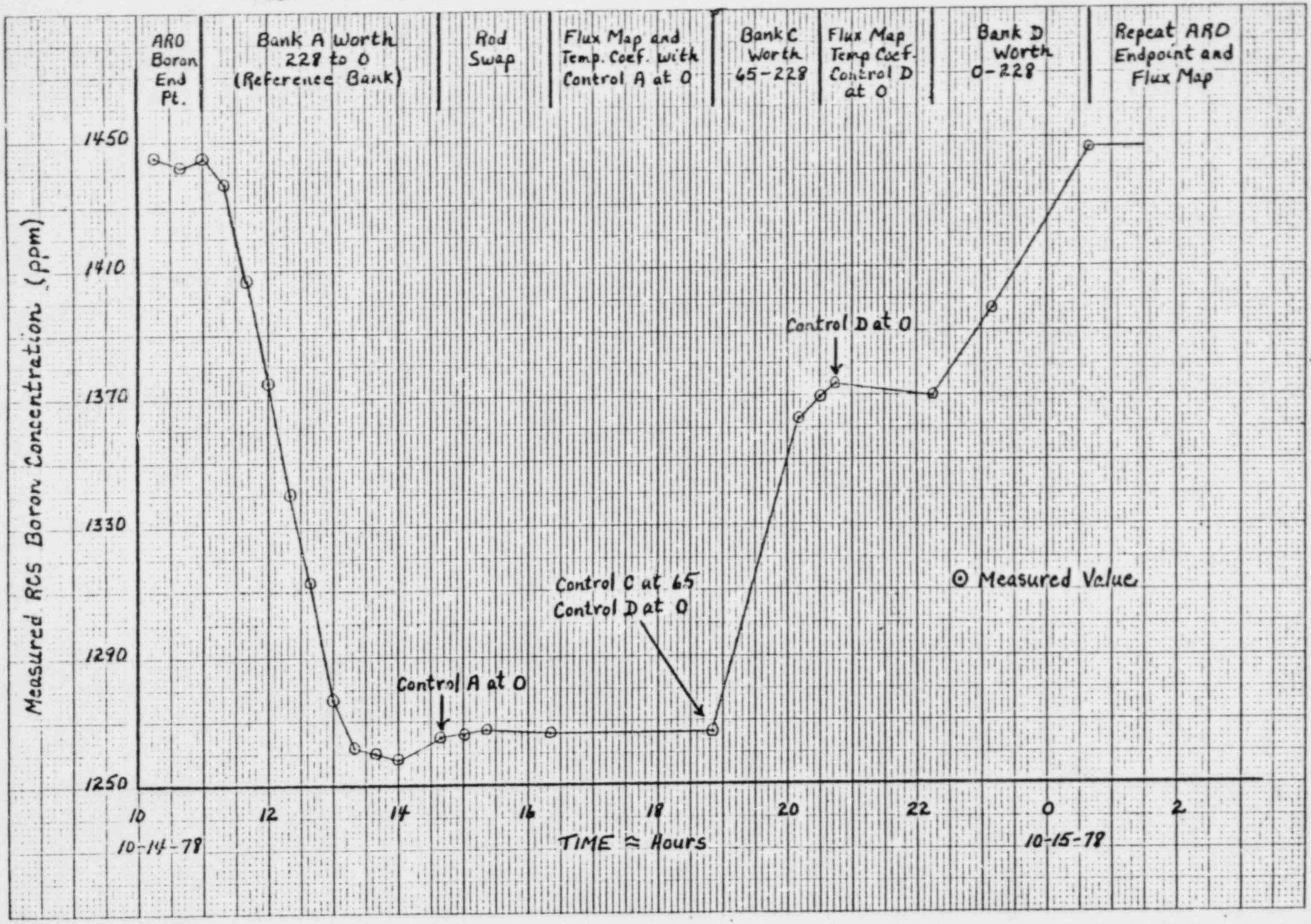
	2 CC	3 SB	4 SA	5 CD	6 CB
$(h_x^M)_o$ (Steps)					
Initial	0.0	0.0	17.0	18.0	17.0
Return	0.0	17.0	18.0	17.0	16.5
Average	0.0	8.5	17.5	17.5	16.7
$(\Delta\rho_1)_x$ (pcm)	0.0	1.3	5.5	5.5	5.0
h_x (Steps)					
Measured, h_x^M	114.5	115.0	126.0	94.5	85.5
Predicted, h_x^P	126.4	126.7	121.7	100.0	92.5
$(\Delta\rho_2)_x$ (pcm)	830	830	740	1028	1125
α_x	0.944	0.963	1.014	1.003	1.028
$\alpha_x(\Delta\rho_2)_x$	783.5	799.3	750.4	1031.1	1156.5

TABLE 3

COMPARISON OF MEASURED/INFERRED
BANK WORTHS WITH DESIGN PREDICTIONS

Bank (x)		$W_x^{M/I}$ (pcm)	W_x^{P} (pcm)	$(\frac{M/I - P}{P})$ (%)
No.	Ident.			
1	CA	1696	1662	+ 2.0
2	CC	912.5	992	- 8.0
3	SB	895.4	983	- 8.9
4	SA	940.1	913	+ 3.0
5	CD	659.4	726	- 9.2
6	CB	534.5	610	-12.4
TOTAL		5637.9	5886	- 4.2

Figure 1 Sequence of Events and Corresponding RCS Boron Concentration Data



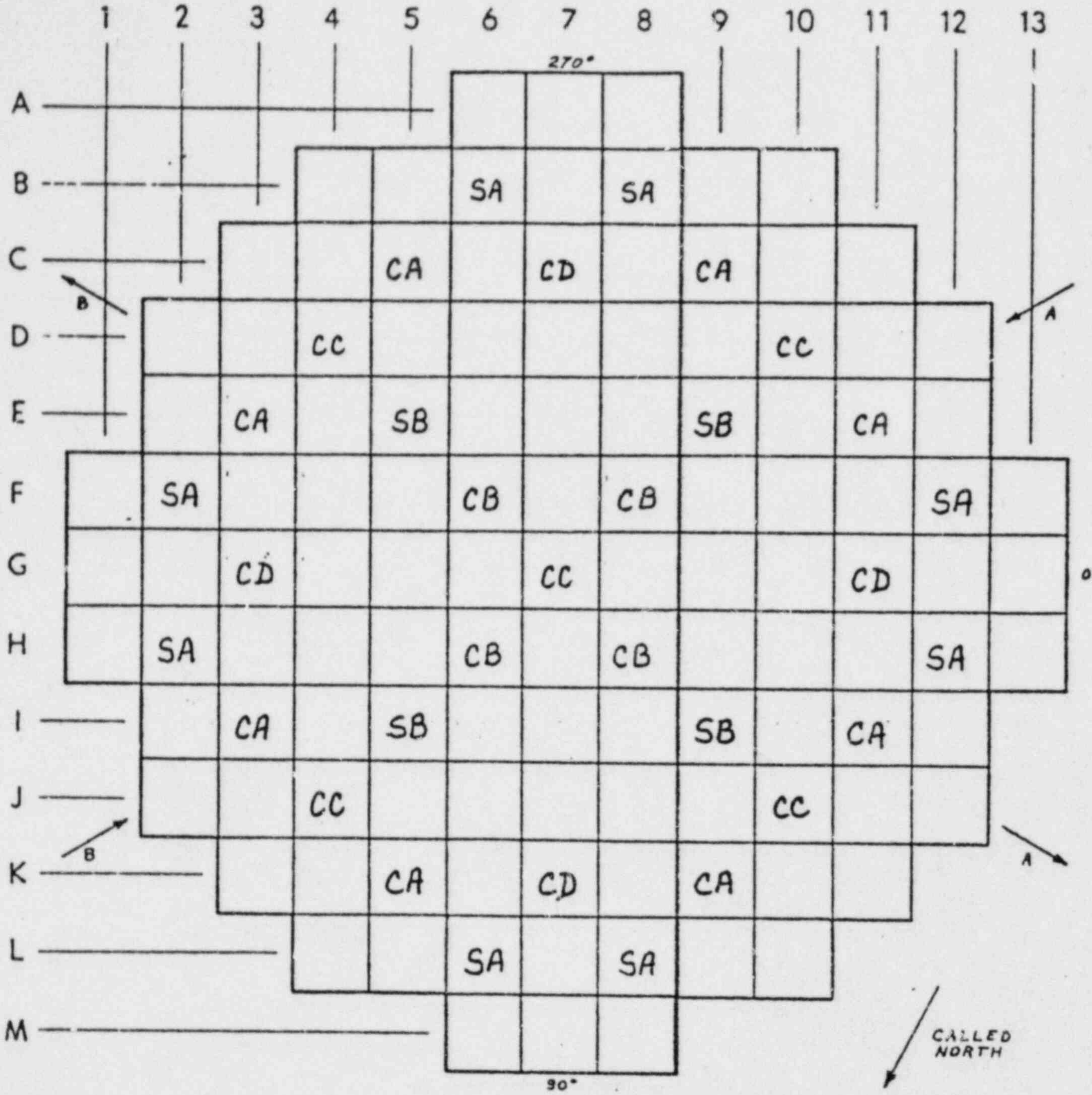
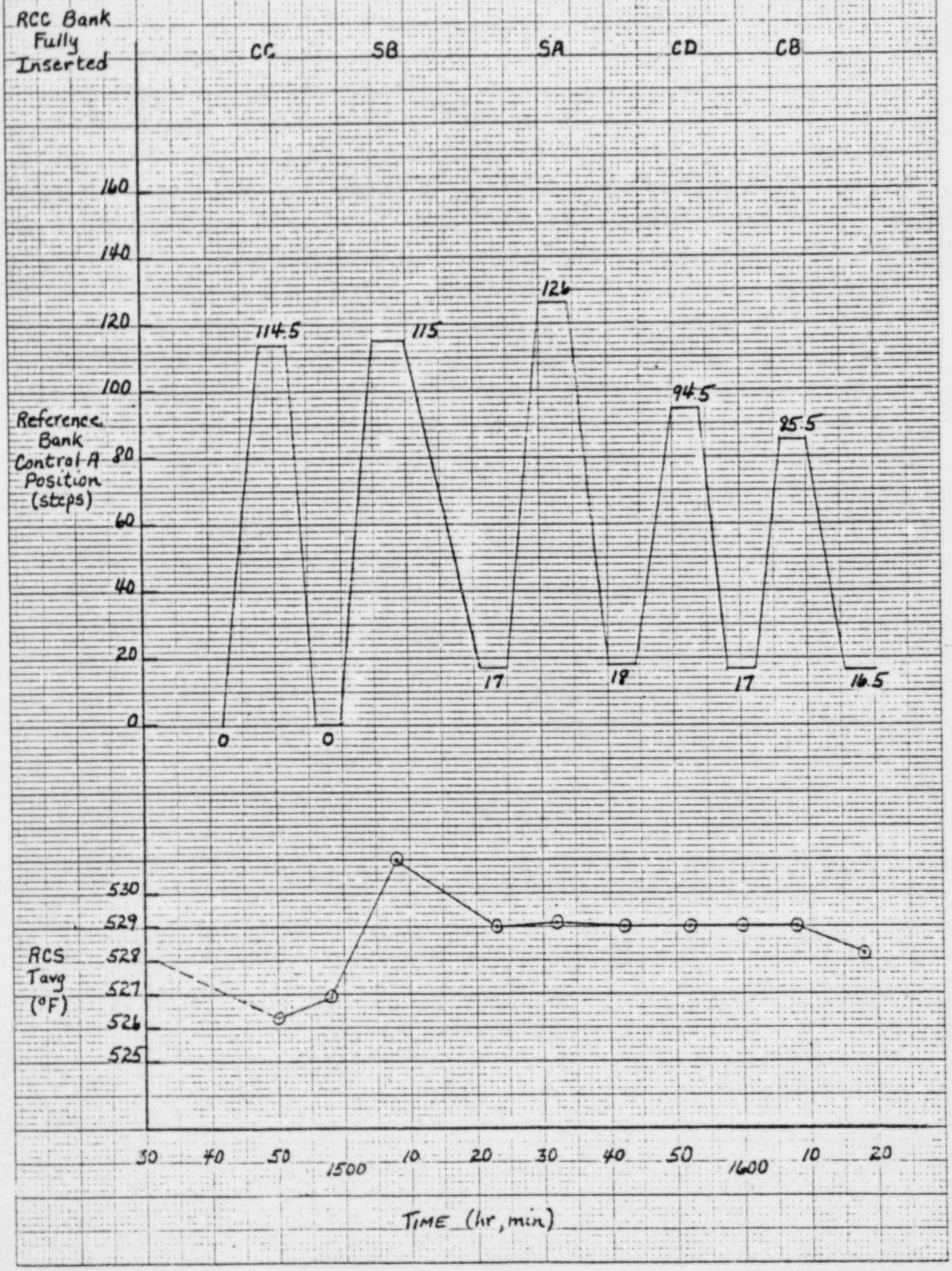


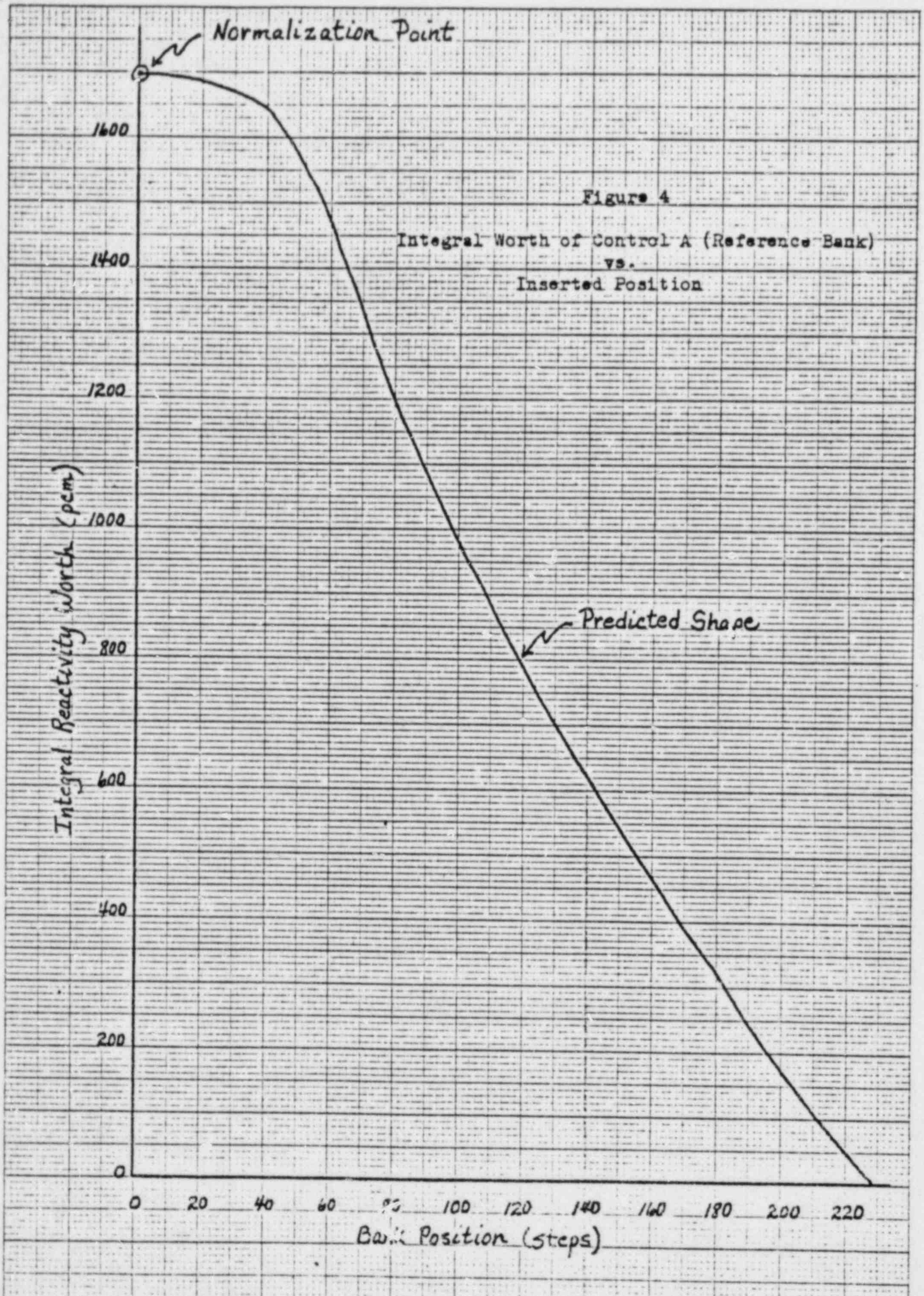
Figure 2

Location of Control and Shutdown RCC Banks

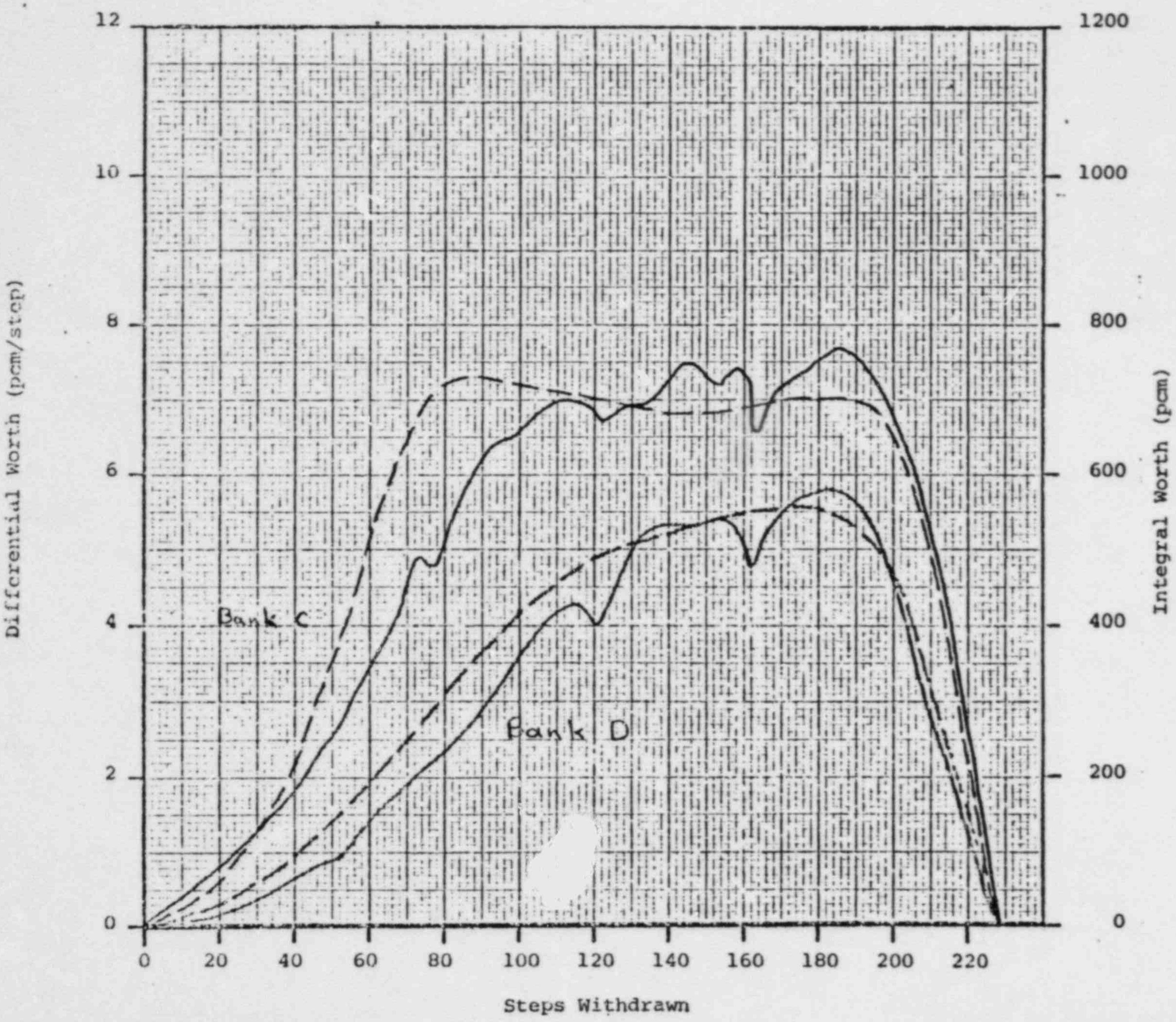
Figure 3

Sequence of Events and Critical Data During Rod Exchange





Normalization Point
Figure 4
Integral Worth of Control A (Reference Bank)
vs.
Inserted Position
Predicted Shape
Integral Reactivity Worth (pcm)
1600
1400
1200
1000
800
600
400
200
0
0
20
40
60
100
120
140
160
180
200
220
Bank Position (steps)



PBNP

Unit I

Cycle 7

BOL HZP

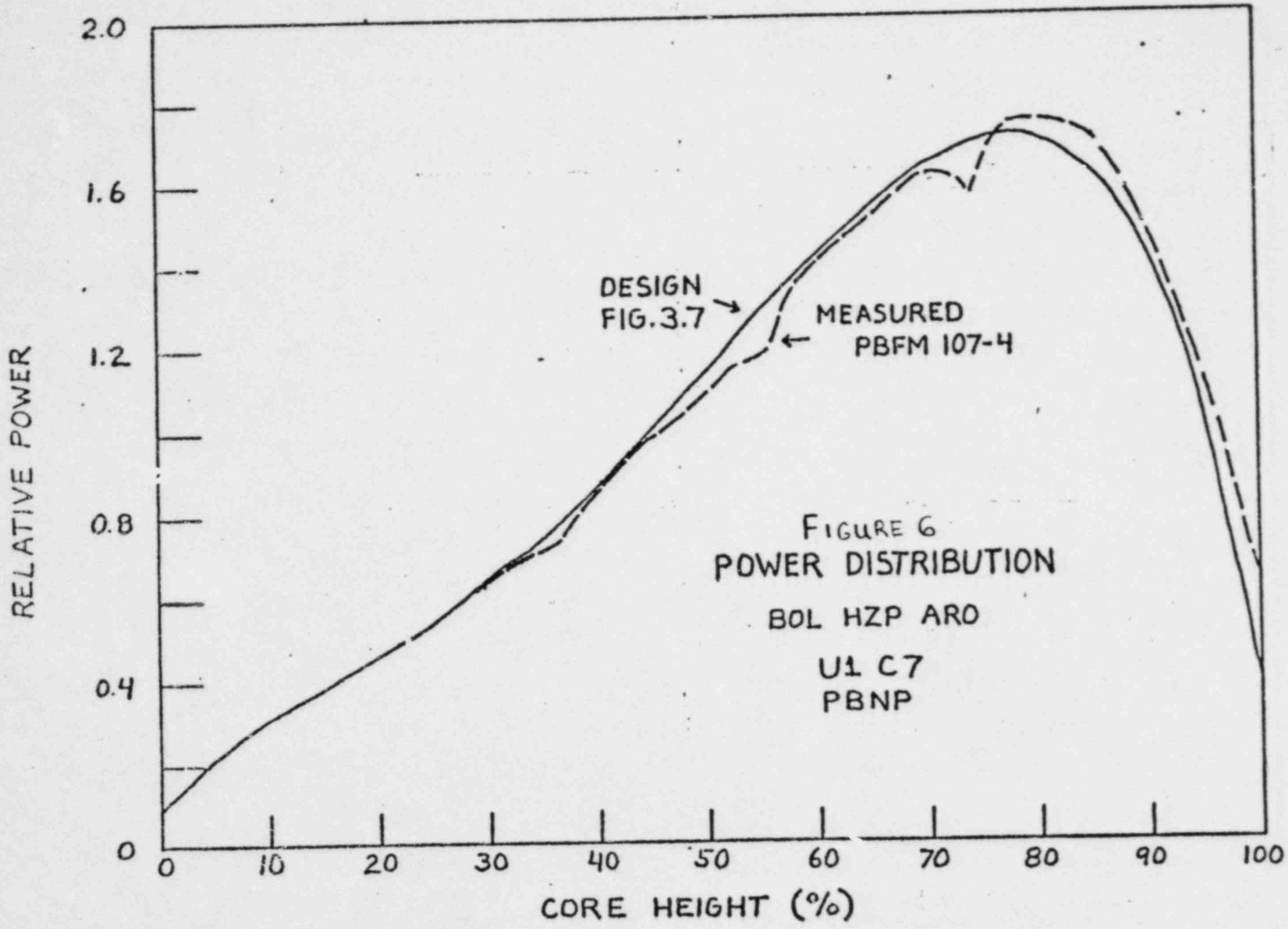
Bank C Worth - Black

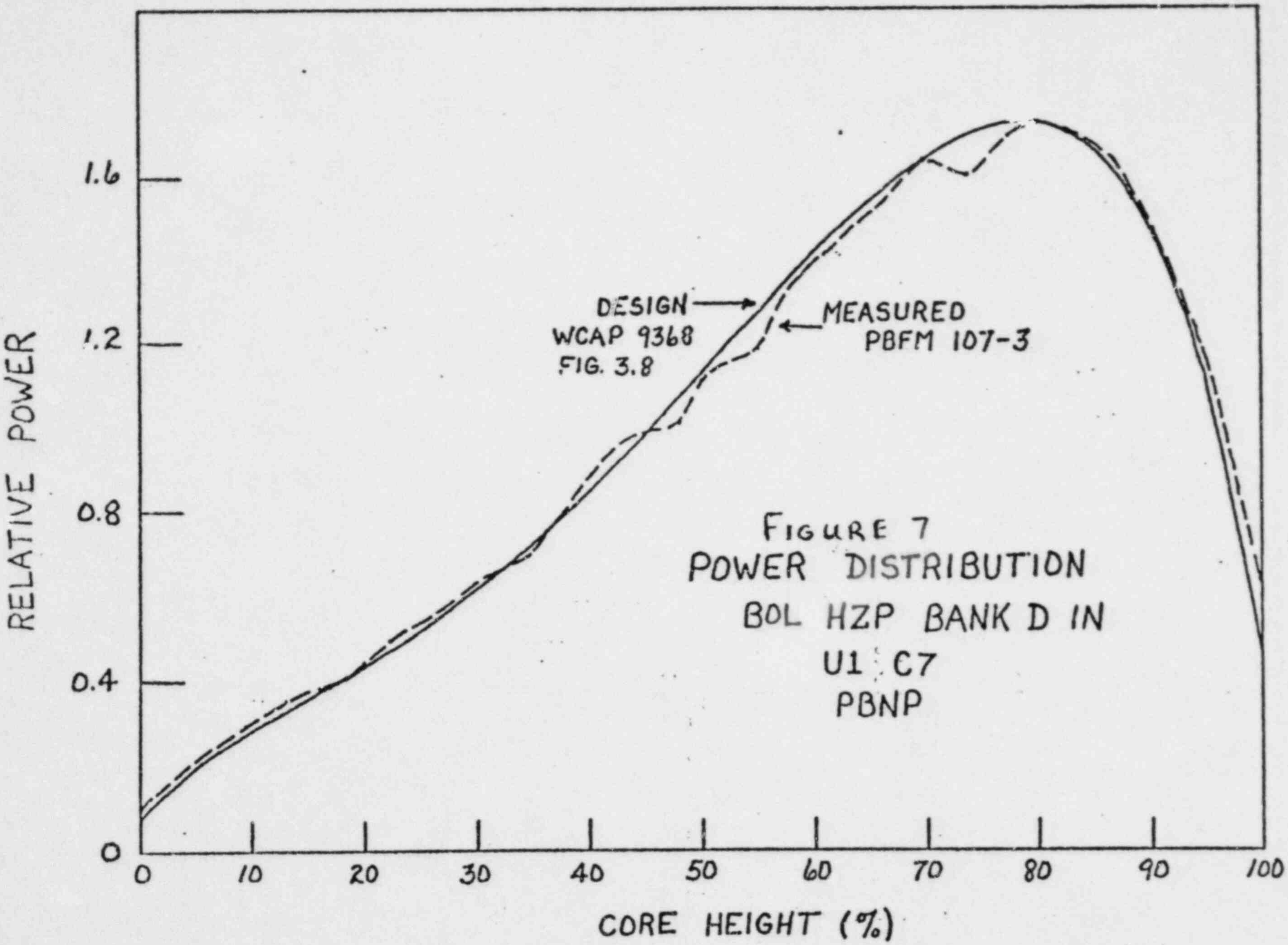
Bank D Worth - Red

Design: - - - - -

Measured: ———

Figure 5


RELATIVE POWER
2.0
1.6
1.2
0.8
0.4
0
0
10
20
30
40
50
60
70
80
90
100
CORE HEIGHT (%)
DESIGN
FIG. 3.7
MEASURED
PBFM 107-4
FIGURE 6
POWER DISTRIBUTION
BOL HZP ARO
U1 C7
PBNP


RELATIVE POWER
0
0.4
0.8
1.2
1.6
0
10
20
30
40
50
60
70
80
90
100
CORE HEIGHT (%)
DESIGN
WCAP 9368
FIG. 3.8
MEASURED
PBFM 107-3
FIGURE 7
POWER DISTRIBUTION
BOL HZP BANK D IN
U1 C7
PBNP

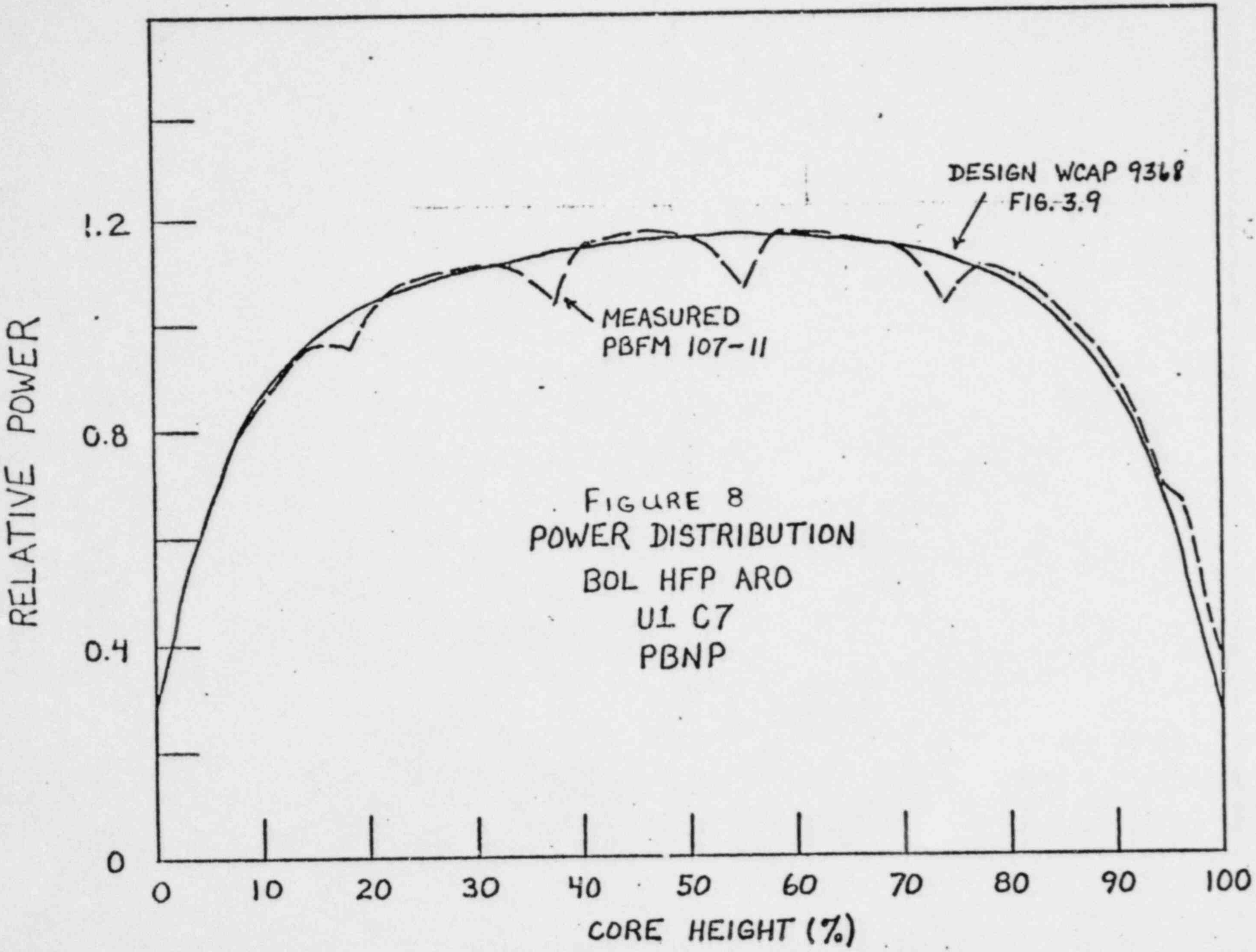
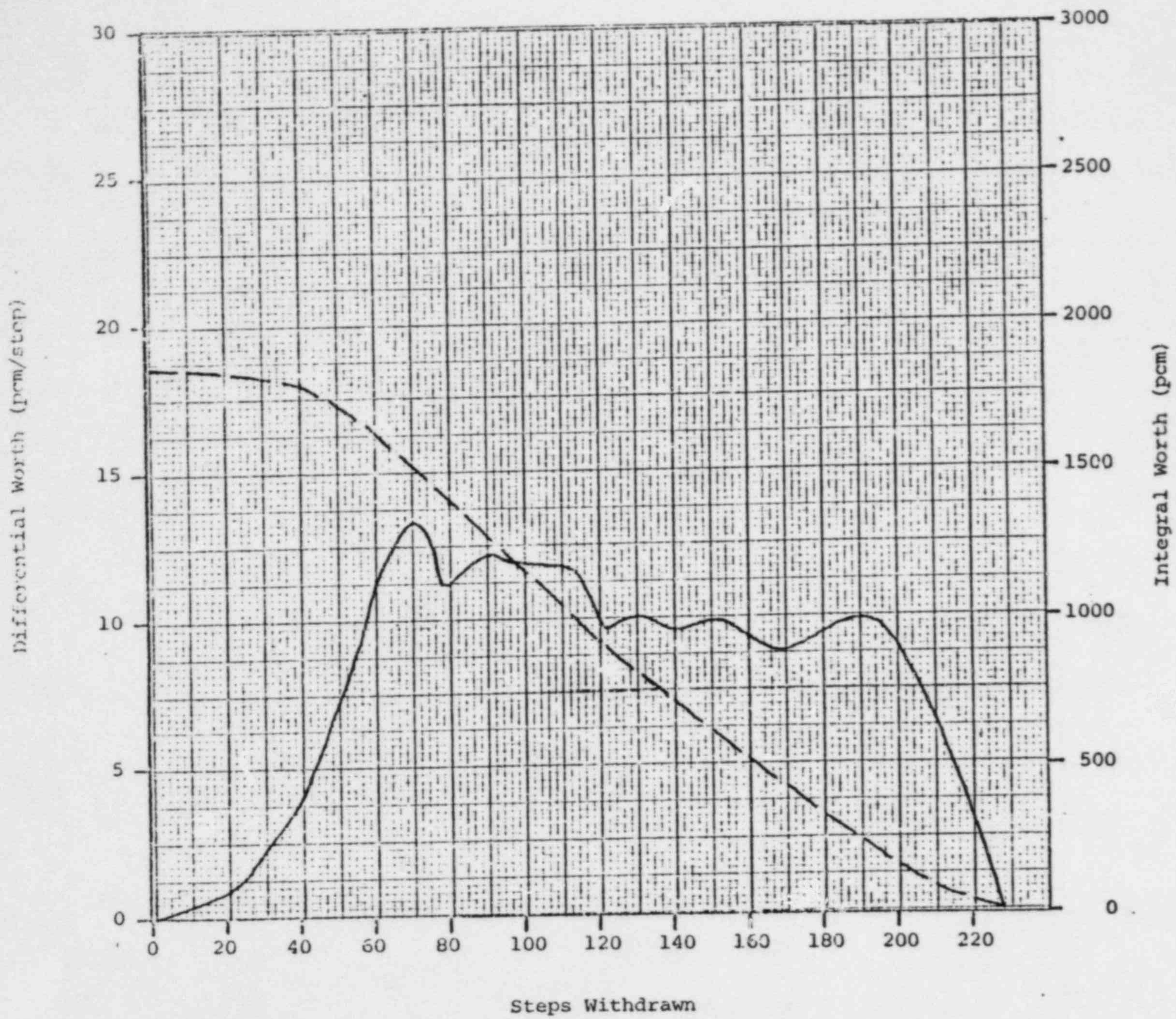


FIGURE 8
POWER DISTRIBUTION
BOL HFP ARO
U1 C7
PBNP



PBNP

UNIT I

CYCLE 7

BOL HZP

BANK "A" WORTH

Integral: - - - - -

Differential: ———

Data Questionable
Do Not Use

Figure 9